

[0011] By switching over connection of neighboring electrodes in the vicinity of an electrode at a position for stimulation between the current source and ground at high-speed, it is possible to adjust the time average of current flowing in and flowing out of the neighboring electrodes. In a preferred embodiment, switching timing is adjusted so that the time average of current flowing in the neighboring electrodes becomes zero. However, as long as formation of a direct current path between an electrode at a position for stimulation (a current source electrode) and neighboring electrodes (as long as a current path is mainly to be formed from the a current source electrode to the ground electrodes) is unlikely, then the time averaging of the amount of current does not have to be zero. Stimulation of nerve axons of deep portions under the skin is therefore possible by forming a current path passing through deep portions under the skin between an electrode at a position for stimulation (a current source electrode) and ground electrodes with the neighboring electrodes therebetween provided.

[0012] An electro-tactile display switches over connections between each electrode and a current source and each electrode and ground over time, and displays information using arrayed electrodes by changing selections of an electrode at a position for stimulation to stimulate and ground electrodes. The foregoing switching of connection of the current source and ground occurring at the neighboring electrodes is carried out at higher speed than the switching connection of the current source and ground for information presentation. A preferred embodiment of switching circuit for carrying out the switching is a half-bridge circuit. A half-bridge circuit is provided with two switches that alternately open and close. When one of the switches is closed (and the other switch is open), an electrode and a current source are electrically connected, and with the other switch is closed (and the other switch is open), the electrode and ground are electrically connected.

[0013] In this specification, "neighboring electrode" refers to at least part of a plurality of electrodes in the vicinity of an electrode (normally one electrode but may also be a plurality) at a position for stimulation. "Neighboring electrode" is by no means limited to immediate neighboring electrodes of an electrode for the stimulation, and may also refer to secondary neighboring electrodes (electrodes neighboring the immediate neighboring electrodes).

[0014] In electrical stimulation using an array of electrodes, with regards to problems where sufficient stimulation is not possible in cases where electrode interval is narrow, it is possible to increase the amount of stimulation without deteriorating spatial resolution of the stimulation.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. 1 is an overall view of an electro-tactile display system;

[0016] FIG. 2 is a view showing a basic electrical stimulation procedure using electrodes arranged in a two-dimensional matrix;

[0017] FIG. 3 relates to a situation where the interval between electrodes is too narrow, in the left side of FIG. 3 shows the situation when the current path passes through shallow sections of the skin but does not stimulate nerves N, and the right side of FIG. 3 shows when the distance between a current source and ground is made to be appropriate by making electrodes surrounding the current source high impedance;

[0018] FIG. 4 shows the most basic resolving method for when electrode interval is narrow and electrodes cannot be made high-impedance, and is a technique where the current source size is made equivalently large;

[0019] FIG. 5 is a view modeling the simplest resistance components for shallow sections of the skin, and a current path can be achieved that is proportional to the square root of the number of the current source electrodes;

[0020] FIG. 6 is a view illustrating a proposed high-speed localized switching technique. By switching over electrodes 2 and 4 at high speed between both current-sourced and grounded states alternately, when time-averaged, this becomes the equivalent to a high-impedance electrode H where current does not flow in or out, as shown in the right side of the diagram;

[0021] FIG. 7A shows an electrode S at a position for stimulation and the neighboring electrodes 1 to 8, and FIGS. 7B, 7C, and 7D are views showing an example of a technique for high-speed localized switching occurring at a two-dimensional matrix of electrodes;

[0022] FIG. 8 is a view showing a visual-tactile conversion system;

[0023] FIG. 9 is a view showing a visual-tactile conversion device combined with a camera, with the left side of FIG. 9 showing an electro-tactile display section T mounted on the upper surface of a device, and the right side showing a camera C mounted on the lower surface of a device;

[0024] FIG. 10 is a view illustrating interpolation using speed during use of a low speed camera;

[0025] FIG. 11 is a view showing interlaced scanning for a camera;

[0026] FIG. 12 shows a cross-section of a finger mount and rounded electrodes;

[0027] FIG. 13 is a view showing concentration of stress on an edge due to elastic body characteristics of a finger;

[0028] FIG. 14 is a view showing interlaced scanning occurring in electrical stimulation. The left side of FIG. 15 shows an example of using a mobile electro-tactile display, and the right side shows a stimulating electrode matrix;

[0029] FIG. 16 is a cross-sectional view of a mobile electro-tactile display;

[0030] FIGS. 17A and 17B show illustrative arrangements for film-shaped force sensors;

[0031] FIG. 18 is a related art configuration for an electrode section and a circuit; and

[0032] FIG. 19 shows a separation of a circuit having a switching circuit.

BEST MODE FOR CARRYING OUT THE INVENTION

[A] An Electro-Tactile Display

[0033] FIG. 1 is an overall view of an electro-tactile display system of the present invention. The system comprises a computer, a current source, a switching circuit and stimulating electrodes. The stimulating electrodes are arrayed electrodes comprised of a plurality of electrodes. Each electrode of the arrayed electrodes is electrically connected to the current source via the switching circuit. A current source electrode is then selected from the stimulation electrodes using a control signal from the computer, supplied with current, and stimulation is provided from the electrode supplied with current.